Biological Evaluation

of Gypsy Moth Populations

on the Monongahela National Forest, West Virginia 2008

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ABSTRACT

In the fall of 2008, personnel from USDA Forest Service, Northeastern Area, Forest Health Protection, Morgantown Field Office and the Monongahela National Forest conducted gypsy moth egg mass surveys on the Monongahela National Forest (MNF). The purpose of these surveys was to estimate gypsy moth population densities through fall egg mass counts, and to assess the need for treatment in 2009. Predicted populations densities were estimated to be sufficient to cause moderate to heavy defoliation on 6383 acres in 2009. Treatment to prevent defoliation is recommended in those areas where the predicted level of defoliation has the potential to cause a reduction in tree growth, reproduction (flowering and seed production), and an increase in tree mortality, all of which can conflict with existing resource management objectives.

INTRODUCTION

Aerial surveys performed by the Forest Service and the State of West Virginia during the summer on the Monongahela National Forest identified 23,419 acres of forest defoliated by the gypsy moth. In a hardwood forest, about 30 percent of the leaves must be eaten for the defoliation to become noticeable during an aerial survey (primary detection technique). Studies of defoliation impacts have shown that growth loss begins when defoliation reaches about 40 percent and re-foliation at about 60 percent (Liebhold et al. 1994). This year's defoliation shows a large increase from the 7,811 and 724 acres mapped in 2007 and 2006. Many of the areas defoliated this year also experienced some level of defoliation in 2007. High gypsy moth population in combination with dry spring conditions, might result in another defoliation event which could lead to a reduction in tree growth, reproduction (flowering and seed production), or tree mortality, all of which could conflict with existing resource management objectives.

The gypsy moth, *Lymantria dispar* (Linneaus) is a non-native defoliator of forest, shade and ornamental trees throughout the Northeastern United States. Since its intentional importation and accidental release in eastern Massachusetts in 1869, the gypsy moth has steadily expanded its range. Despite many attempts to halt its spread westward from the northeastern United States, West Virginia experienced its first gypsy moth defoliation in 1985. Since that time, the gypsy moth has defoliated nearly 2.1 million acres in the state.

The gypsy moth produces one generation per year. Larvae begin hatching from egg masses in late April and early May when tree buds begin to open. At this time, larvae go through an obligatory dispersal period where they leave the vicinity of the egg, moving upward and spinning a thread of silk as they go (Leonard 1981). Eventually the wind catches the larvae and disperses them. Airborne larvae are carried and deposited some distance downwind from the source with the following results: 1) larvae will land on or crawl onto acceptable host plants and begin feeding; 2) larvae will land on either acceptable or unacceptable and re-disperse; 3) larvae will be deposited into areas unacceptable for survival and re-dispersal where they will die (Mason and McManus 1981). The larvae feed for two to three months completing their development by late June and early July and seek sheltered areas in which to pupate. The pupal

period last anywhere from 10 days to two weeks. After emerging from the pupal case the females, which cannot fly, crawl a short distance and emit a pheromone scent to attract males. After mating, the female lays a single egg mass that contains from 75 to 1,000 eggs, which she covers with hairs from her abdomen giving it a fuzzy brown texture and color. The egg masses over winter and hatch the following spring.

The number of host trees and shrubs fed on by the gypsy moth exceeds 300 species, with species of oaks (*Quercus* spp.) ranked among the most favored (Leonard 1981). Gypsy moth is an outbreak species whose populations can remain at low levels for several years, then undergo large population increases in a matter of one or two years. After populations have increased to an outbreak density they can remain high for one to five years, outbreaks decline suddenly to low densities where it is difficult to find any life stage (Liebhold et al. 2000). The main effects of gypsy moth feeding on individual trees involves the depletion of root carbohydrate food resources leading to a reduction in growth, reproduction, and increased vulnerability to secondary agents of mortality. Heavy defoliation forces re-foliation which occurs when about 60 percent of the foliage is lost (Liebhold et al. 1994). This re-foliation uses carbohydrate reserves in trees and can increase their vulnerability to drought and to other insects and diseases. This defoliation and subsequent tree mortality can alter wildlife habitats, change water quality and temperature, increase forest floor temperatures and light levels and reduces aesthetic, recreational, and property values of forests and urban environments.

OBJECTIVES

The objectives of this biological evaluation were to: 1) accurately assess current gypsy moth population densities within susceptible forest types on the Monongahela National Forest; 2) determine the likelihood of unacceptable impacts on MNF forest resources occurring in the next growing season; 3) develop treatment alternatives and recommendations to suppress gypsy moth outbreaks likely to cause unacceptable impacts.

METHODS

The guidelines used to evaluate the risk of defoliation include: 1) current defoliation level as defined by aerial surveys; 2) previous defoliation events; 3) number of egg masses/acre; 4) size and condition of the egg masses; 5) presence of disease and parasites; 6) availability of preferred food (mainly oaks); 7) risk of larval blow-in following egg hatch.

Based on the results of this years aerial survey, MNF resource values (table 1), and maps provided by the West Virginia Department of Agriculture Cooperative Gypsy Moth Program, 37 areas were identified and surveyed this year (Figure 1). Defoliation predictions for 2009 within survey areas were based on egg mass density, egg mass length, population trends and host type (Liebhold et al. 1994, Liebhold et al. 1993). Intervention thresholds for each area were established based on resource management objectives provided by the MNF and included nuisance abatement, the prevention of defoliation and growth loss, the prevention of tree mortality or a combination of objectives (Table 2).

The number of survey plots established within each unit was based on the West Virginia Department of Agriculture Gypsy Moth Cooperative State and County Landowner Egg Mass Procedure Guide (Table 3) and were evenly distributed throughout each of the sample areas in susceptible forest types.   A minimum of three sample points were established within each area with additional survey sites being chosen based on areas acreage. Ecological land type data provided by the MNF was used to insure that sample points were located in susceptible host type (mainly oaks). A total of 357 sample points were established throughout the 37 survey areas (Table 1).

During this survey, 1/40th acre (18.6-ft radius) plots were used to estimate egg mass densities within susceptible forest type areas. At each sample point, a 1/40th acre fixed radius plot was established and the percent new and old egg masses were determined by inspection and visual count. An inspection of all egg masses within reach helped estimate the portion of new to old egg masses at each plot. Egg masses visual counts consisted of a tally of all egg masses observed on the overstory trees, understory vegetation, ground litter and duff. The total number of egg masses observed for each plot was summed and multiplied by the ratio of new egg masses to old egg masses (Liebhold et al. 1993) and multiplied by 40 to calculate the number of egg masses per acre. This was repeated for each plot and the results summed and averaged for a single density value for the unit. In addition to density the standard error of the egg mass estimate was also determined to evaluate how much confidence could be placed on the estimate. Three egg masses at each plot were also measured and average to provide additional information on condition and trend of the gypsy moth populations.   Small egg masses (i.e. < 20 mm in length) are indicative of a declining population, while large egg masses (i.e. > 30 mm in length) of an increasing population (Liebhold et al. 1994).

RESULTS

The 37 survey areas are represented in Figures 1 and the gypsy moth population densities in each area is summarized in Table 4. Overall, average egg mass densities ranged from 0-12,868-egg masses/acre. Ten of the survey areas, (Table 4) encompassing 5,216 acres contain egg mass densities sufficient to predict heavy (>60%) defoliation, based on a threshold of 1000(+) egg masses per acre.

DISCUSSION

The greatest potential for heavy defoliation in 2009 exists within those survey areas where the egg mass counts exceed the 1,000-egg masses/acre threshold. Defoliation of this intensity could lead to permanent tree damage (crown decline, dieback and mortality). The potential for "moderate" defoliation in 2009 exists within those areas where the egg mass counts are between 500–1,000 egg masses/acre. Defoliation at this level creates nuisance larval densities and moderate defoliation that can adversely effect tree growth and have an impact on recreation and view-sheds. Survey plots with egg mass count of 500 egg masses/acre or less are likely to have "light" or noticeable levels of defoliation levels with little impact on growth loss, but nuisance larval densities should be expected.

Predicting the extent of impact of gypsy moth on individual trees or areas is uncertain. In cases in which two or more consecutive years of defoliation have occurred some level of prediction can be made based on changes in egg mass density, size, and presence of control factors (i.e. predators, parasites and diseases).   Gypsy moth population trends (density and egg mass length) in nearly every area are increasing (Table 4). Surveys completed before leaf fall revealed that few if any trees re-foliated because of gypsy moth defoliation. Since defoliation reduces the trees ability for future photosynthesis and re-foliation events causes the tree to expend carbohydrate reserves during re-foliation it is these factors that must be considered when deciding whether intervention is necessary or warranted.   Other factors that need to be considered are the condition of the trees at the time of defoliation (i.e. stand stocking, age and amount of susceptible species present). Studies have shown (Gottschalk 1989), that reduced growth, mast abortion branch dieback or in some cases tree mortality, has been observed following a single year of heavy defoliation. Should a subsequent period of drought or other stressors occur during a defoliation event or even after, the potential impact on individual trees may be is compounded.

Trees that receive light-moderate defoliation (40 to < 60 percent) are not likely to refoliate and expend food resources but are likely to show some level of growth loss (Liebhold et al. 1994). In hardwood forests, about 30 percent of leaves must be eaten for defoliation to become noticeable and levels below this are likely the result of background levels of feeding and damage.

The natural control factors operating in the survey areas were not quantitatively surveyed, but observations indicate that the size of new egg masses was moderate to large with an almost constant presence of *Ooencyrtus kuvanae,* a parasitic wasp specific to gypsy moth eggs. Larval cadavers were collected during the surveys and were found to be harboring resting spores of the gypsy moth fungus, *Entomophaga maimaiga*. This fungus is known to be present wherever gypsy moth is distributed in West Virginia, and was considered to have influenced the successful reduction of those gypsy moth infestations on the MNF sprayed in 2001 and 2003 as well as those unsprayed infestations predicted to be defoliated in 2002 and 2004. It is likely this fungus could adversely influence gypsy moth infestations on the MNF especially if there is wet spring weather. The gypsy moth nucleopolyhedral virus was also present in dead larvae collected, but this pathogen operates at high larval density and does not kill as quickly as the fungus so its effects are usually masked by the presence of the fungus.

GYPSY MOTH MANAGEMENT OPTIONS

For 2009, three management options have been evaluated based on decisions by the MNF for managing gypsy moth populations. The intervention option is offered based upon the following two treatment objectives: 1) protect host tree foliage to prevent mast failure and tree mortality; and 2) reduce gypsy moth population below the treatment threshold. Each option is discussed below.

NO ACTION OPTION

It is possible that gypsy moth populations could collapse due to the presence of the gypsy moth nucleopolyhedrosis virus (NPV) or the gypsy moth fungus, *Entomophaga maimaiga.* Where defoliating gypsy moth populations are greater than 500 egg masses/acre viral epizootics generally manifest themselves only after significant tree defoliation has already occurred. Gypsy moth populations will usually peak in two-three years once they reach defoliating levels and then collapse as a result of NPV or fungal activity. Residual populations following such a collapse will likely remain at low densities for three-six years before rebuilding to defoliating levels. Although it is difficult to accurately assess the sequence of such events, it is unlikely that a collapse will occur since these areas are in the first or second year of infestation and there is an abundance of large egg masses.

Should this option be selected, it is likely that defoliation will occur and population densities will increase in newly infested stands and expand to currently uninfested areas.

MICROBIAL INSECTICIDE OPTIONS

The second option is to use a microbial insecticide to manage gypsy moth populations. The only biological insecticide currently registered and commercially available for gypsy moth control is the microbial insecticide, *Bacillus thuringiensis* variety *kurstaki (B.t.k).* This microbial insecticide is available through two manufacturers containing both the spore and crystal as the entomopathogenic ingredients (Reardon et al. 1994) and has been used extensively in suppression projects throughout the U.S. in both forested and residential areas. *B.t.k.* is a bacterium that acts specifically against lepidopterous larvae as a stomach poison and therefore must be ingested. The major mode of action is by mid-gut paralysis, which occurs soon after feeding. This results in a cessation of feeding, and death by starvation. *B.t.k.* has been shown to impact other non-target caterpillars that are exposed to the treatment and are actively feeding. *B.t.k.* is persistent on foliage for about 7-10 days.

B.t.k is not target specific and may reduce the populations of non-target organisms either as a consequence of direct toxicity or indirectly, by reducing food supplies. Several factors must be taken into account when using B.t.k such as: 1) the potential for non-target extirpation in the proposed spray area; 2) the life stage present and any deferential susceptibility to *B.t.k* that may exist between species of non-target organisms; 3) the size and uniqueness of the area beginning proposed for treatment. Since much of this site-specific data regarding non-target organisms may not be known for many areas the potential benefits must be weighed against any potential impacts to non-targets.

B.t.k. formulations are available as a flowable concentrate. The normal application rates range from 24-36 billion international units (BIUs) per acre in a single or double application. *B.t.k.* can be applied either undiluted or mixed with water for a total volume of ½-1 gallon per acre. With proper application, foliage protection and some degree of population reduction can be expected with one application and with two applications both foliage protection and a greater degree of population reduction are likely. Because *B.t.k.* is a biological insecticide, the degree of population reduction varies and may depend on, at least in part, the selected application rate, relative health of the population (building vs. declining), population densities, weather (rain and

temperature), the feeding activity of the larvae following treatment, and the actual potency of the product.

A second microbial insecticide that is registered and available in limited quantities is the formulated nucleopolyhedrosis virus called Gypchek® (U.S. Forest Service, USDA, Washington, DC). This product is not available commercially but is produced in limited quantities by a cooperative effort of the USDA Forest Service and the Animal Plant Health Inspection Service (APHIS). The active ingredient in Gypchek formulations has a very narrow host range (lymantriids) and occurs naturally in gypsy moth populations. Normally the virus reaches epizootic proportions when gypsy moth populations reach high densities as a result of increased transmission within and between gypsy moth generations. The application of Gypchek to gypsy moth populations simply expedites this process by increasing the exposure of the virus at an earlier stage. Healthy, feeding gypsy moth caterpillars become infected by ingesting contaminated foliage and soon stop feeding and die.

The efficacy of Gypchek treatments to reduce gypsy moth populations has been quite variable. Because of the short period of viral activity on foliage (3-5 days) as well as other biological factors such as feeding activity and weather conditions, it has been difficult at best to project treatment efficacy. Most often foliage protection can be achieved but significant reductions in gypsy moth densities do not always occur. Should inadequate population reduction occur, areas would need to be treated again the following year. The normal application rate of Gypchek is $4x10^{11}$ occlusion bodies (OB's) per acre applied once.

With the previously described options in mind, the following alternatives are offered.

Alternative 1.   -No action

Alternative 2   -One aerial application of *B.t.k.* at the rate of 36 BIUs in a total mix of ¾ gallons/acre.

Alternative 3   -Two aerial application of *B.t.k.*, as in alternative 2, applied 4-7 days apart.

Alternative 4   -One aerial application of Gypchek at an application rate of $4x10^{11}$ occlusion bodies (OB's)/acre.

Alternative 5   -Two aerial applications of Gypchek as in alternative 4, applied at $2x10^{11}$ occlusion bodies (OB's)/acre applied in two applications, 3-5 days apart.

RECOMMENDATIONS

It is recommended the MNF decide in favor of alternative two (one aerial application of *B.t.k.*) in the Lake Sherwood area covering 4,400 acres (Figure 8). National Forest resource values, such as recreation, timber, and wildlife would be protected by the suppression of potentially damaging gypsy moth populations where these values are at the greatest risk. This

decision would prevent additional unacceptable damage to forest resource values and uses caused by defoliation likely during 2003, especially in areas defoliated in 2002 and 2001.

For the proposed spray blocks (where gypsy moth egg masses exceed the 1,000 egg masses/acre threshold) *B.t.k* would be expected to prevent moderate to heavy defoliation that results in tree permanent tree damage or mortality. For those blocks with gypsy moth egg mass densities that are above the 500 egg masses/acre threshold treatment would be expected to prevent larval nuisance and light to moderate defoliation that adversely affects recreation view-sheds, values and uses.

Alternative 2 is recommended over the other alternatives based on the following considerations.

1) A double application of *B.t.k.* on all 4,400 acres would likely to provide foliage protection and a population reduction but this alternative is also less economical and logistically more complicated than the recommended alternative.

2) A single and/or double application of Gypchek is likely to provide foliage protection and a population reduction. Gypchek has a shorter activity period (3-5 days) then the recommended single *B.t.k* (7-10 days) alternative and is also less economical due to the cost of the carrier.

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Table 1. Areas identified for evaluation for gypsy moth on the Monongahela National Forest

Area	Priority	Acres	Number of Plots	Notes
1	High	1028.42	14	Lake Sherwood Recreation Area, Important Veiwsheds
2	High	1921.31	23	Second Successive defoliation event, Important Veiwsheds
3	High	469.81	9	Second Successive defoliation event,
4	High	420.79	9	Second Successive defoliation event, Severe Defoliation 2008
5	High	153.40	6	Second Successive defoliation event, Severe Defoliation 2008
6	High	336.86	8	Second Successive defoliation event
7	High	1433.02	18	Second Successive defoliation event
8	High	66.52	4	Second Successive defoliation event
9	High	451.73	9	Second Successive defoliation event
10	High	203.77	7	Second Successive defoliation event
11	High	283.63	7	Second Successive defoliation event
12	High	553.45	10	Second Successive defoliation event
13	High	4169.70	50	Second Successive defoliation event
15	Medium	25.82	3	Second Successive defoliation event, Severe Defoliation 2008
16	Medium	1405.36	18	Important Veiwsheds, Severe Defoliation 2008
17	Medium	308.56	7	Important Veiwsheds
18	Medium	565.61	10	Second Successive defoliation event, Important Veiwsheds
19	Medium	1295.28	16	Adjacent landowner
20	Medium	114.75	6	Adjacent landowner
21	Medium	189.63	6	Adjacent landowner
22	Low	197.27	6	Important Veiwsheds
23	Low	344.40	8	Important Veiwsheds
24	Low	144.84	6	Important Veiwsheds
25	Low	50.22	3	Important Veiwsheds
26	Low	1909.63	23	Important Veiwsheds
27	Low	283.94	7	Important Veiwsheds
28	Low	82.30	4	Important Veiwsheds
29	Low	346.96	8	Important Veiwsheds
30	Low	44.88	3	Important Veiwsheds
31	Low	5.04	3	Important Veiwsheds
32	Low	125.16	6	Important Veiwsheds
33	Low	656.77	11	Important Veiwsheds
34	Low	324.76	8	Important Veiwsheds
35	Low	769.78	12	Important Veiwsheds
36	Low	1,595	13	Calvin Price boundary, Adjacent landowner
37	High	130	5	Adjacent landowner
Totals		22,408	357	

Table 2. Egg mass density thresholds for resource management objectives.

Threshold (egg masses/acres)	Predicted Defoliation	Objectives
250	< 30[1] %	Nuisance Abatement
251-500	30 - 40 % (Light)	Prevent Noticeable Defoliation
501-1000	41 - 60 % (Moderate)	Prevent Growth Loss
>1000	> 60 % (Heavy)	Prevent Mortality

[1] None or background level of defoliation.

Table 3. Minimum number of 1/40 th acre gypsy moth sample plots based on survey area acreage.

Survey Area (Acres)	Minimum number of sample plots
<50	3
51-100	4
101-200	5
201-300	6
301-400	7
041-500	8
501-600	9
601-700	10
701-800	11
801-900	12
901-1000	13
>1000 acres, add 1 plot for each additional 100 acres	

Table 4. 2008 Gypsy moth egg mass survey results for the Monongahela National Forest.

Area	2008		2007		Egg Mass Threshold	2009 Defoliation Prediction[+]	Notes
	Egg Mass Density[*]	Standard Error	Egg Mass Density	Standard Error			
1	0	0	0	0	250	0	-
2					251-500		
3	112	167	0	0	251-500	< 30%	
4	1,505	424	624	225	251-500	46%	V[1], F[2]
5	2,420	716	1,719	1,254	251-500	60%	V[1], F[2]
6	955	439	452	288	251-500	37%	V[1], F[2]
7	4,460	2,247	11,254	9,853	251-500	80%	V[1], F[2]
8	133	133	40	40	251-500	< 30%	F[2]
9	373	219	97	58	251-500	< 30%	F[2]
10	740	206	287	97	251-500	< 30%	V[1], F[2]
11	338	38	0	0	251-500	< 30%	V[1], F[2]
12	74	67	0	0	251-500	< 30%	
13					251-500		
15	1,026	813	123	26	501-1000	33%	V[1], F[2]
16	4,880	4,734	593	448	501-1000	82%	V[1], F[2]
17	731	62	31	31	501-1000	< 30%	V[1]
18					501-1000		
19					501-1000		
20	1,026	813	123	26	501-1000	33%	V[1], F[2]
21	11,770	6,915	1,439	989	501-1000	90%	V[1]
22	5,262	3,010	563	490	>1000	80%	V[1], F[2]
23	933	452	166	61	>1000	41%	V[1], F[2]
24	40	23	30	19	>1000	< 30%	
25	0	0	20	11	>1000	< 30%	F[2]
26	12,868	4,384	1,436	366	>1000	90%	V[1], F[2]
27	1,156	591	43	43	>1000	43%	V[1], F[2]
28	1,693	948	0	0	>1000	62%	F[2]
29					>1000		
30	227	67	32	32	>1000	< 30%	V[1], F[2]
31	4,322	2,461	847	518	>1000	81%	V[1], F[2]
32					>1000		
33	728	321	127	60	>1000	33%	F[2]
34					>1000		
35	470	262	70	43	>1000	29%	F[2]
36	1,033	588	1,300	890	>1000	41%	V[1], F[2]
37	60	60	60	60	>1000	30%	F[2]

[*]Egg masses/acre; [+] Weibull function (Liebhold et al. 1994); [1] gypsy moth nucleopolyhedrosis virus (NPV) present; [2] gypsy moth fungus, *Entomophaga maimaiga* present,

Figure 1. 2008 Monongahela National Forest Gypsy Moth survey areas.

Fall 2008 Gypsy Moth Egg Mass Surveys

1 inch equals 13,363 feet
0 0.5 1   2 Miles

UTM Nad 83, Contour Interval = 20 ft

created 11/5/08 AKS

State Treatment Blocks
Treatment Blocks 2009
Ownership